CostQuest Associates (CQA)
Economic Research & Analysis

MTPCS USF Model Documentation
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Introduction

MTPCS, LLC d/b/a Cellular One ("MTPCS") asked CostQuest Associates to develop the modeled total investment and monthly costs associated with building and maintaining advanced mobile broadband networks across Louisiana. The modeled results MTPCS asked CostQuest to develop provides estimated costs not only for unserved areas, but for all areas regardless of the type of existing coverage.

Modeling Concepts

Whether considering forward looking economic costs, reverse auctions, or cost accounting methods, a model of some sort forms the necessary background for universal service funding. Indeed, every current universal funding program actually relies upon both a "cost model" and a "support model".

A "Cost Model" is a systematized collection of mathematical procedures that takes as inputs geographic and non-geographic data and that produces an estimate of the cost of providing a telecommunications service. As such, a cost model is designed to provide a normalized measure of investment and operational costs so that policy choices, technologies, carriers and geographic areas can be compared on a fair and impartial basis. For example, a cost model will help address the impact to cost of broadband options; the cost of various technologies, costs under different market conditions, and assumptions concerning the components of a network.

A "Support Model" uses a mathematical procedure that takes cost data as an input, sets a standard for acceptable customer payment or affordability, applies a funding method (regulatory or carrier based), to produce an amount of subsidy/ support necessary for the carrier to deliver the modeled services to high cost customers.

All support models rely on the integrity of cost data from the cost model to provide a solution. CostQuest's dual focus on this project was to develop robust and accurate cost model results and investigate support model parameters which provide the user with an understanding of support policy decisions. It is ultimately up to the users of this CostQuest model platform to determine the final inputs and overall design of the Support approach and the various policy decisions that influence the Model's results.

Overview of Project

In summary, CostQuest is presenting a Forward Looking Economic Cost Model that estimates the costs for wireless mobility and broadband services in Louisiana. Using the cost output, the CostQuest model then provides a platform to investigate high-cost support issues.

The Cost Model is based on:

- An application which realistically models the appropriate investments and costs to operate and maintain a mobile broadband network. The model is based upon 4G investments and costs but also could be utilized to project 3G investments and costs.
- Methodologies that are consistent with FCC objectives in developing Forward Looking Costs for universal service.
- Methodologies that are consistent with recent efforts by the FCC to understand the cost of broadband deployment.
- A design that captures the upfront investment to deploy and the ongoing cost to maintain a mobile broadband network.
- The assumption that these networks will be sensitive to the size of demand, frequency propagation, geography of the study area and network engineering characteristics.
- The notion that operational costs are incurred by an efficient provider along with the capital costs associated with the network deployment.

The Support Model provides toggles that allow the user to:

- Determine the level of geography for funding development
- Input an overall cap on total funding
- Input a support cap to limit the per subscriber funding
- Input a funding cutoff to exclude funding to customers whose cost are excessive
- Input the assumed level of competition
- Input the assumed level of subscriber Revenue (i.e., a benchmark) above which an area would be uneconomically viable to serve

Based on these inputs, the Support model then determines the geographic areas that require funding, thereby providing an efficient disbursement of the limited support dollars.

High Level Methodology

The purpose of this modeling effort is to estimate the cost to serve areas (and users), determine commercial viability, and identify areas in need of additional funding support. The high level methodology used in the modeling includes:

- Determination of the costs to maintain and operate the modeled network assets, service the customers, and support commercial business employees[1]
- Assessment of whether a service area is commercially viable (i.e., can operate at a positive contribution margin) or is in need of additional support (i.e., would operate at a negative contribution margin)

Further explanation of the methodology

Coverage Analysis – Each modeled state jurisdiction was divided into areas approximating the coverage of a single wireless base station using spectrum currently available to commercial mobile radio service providers (cell coverage areas). These cell coverage areas (varying in size from less than one square mile to as much as 310 square miles) were superimposed over the targeted jurisdictional coverage area. Those cells without any population or roads were dropped from further analysis[2]. It was assumed that new technology was needed in each of the remaining cells, providing an estimated count of new technology investment sites needed to provide the desired 4G service coverage.

Capital Investment Development – Based on the count of cell coverage areas and an assumed mix of owned and leased tower sites, an investment profile was developed and applied to the count of cell coverage areas requiring leased towers and the count of cell coverage areas requiring a tower build. Estimates of the investment required were drawn from industry sources. The model also develops the backhaul and core network investments necessary to support the network operation.

Monthly Expense Development – Recent public financial reports for wireless operators were used to establish the basis of expenses for network, customer, general, and administrative functions. The public data was analyzed and converted to comparable industry accounting records to develop detailed cost inputs that were driven on either cell coverage area or the number of subscribers. Investment cost annualization, which captures depreciation along with financing costs and taxes, were included with operational expenses to produce a total monthly expense. This total monthly expense was allocated to each subscriber in the target service area and rolled up to the census block the subscriber was within to derive a monthly cost per user per census block.

[1] This study is not an attempt at creating an actual final cost or a precise tower count necessary for building and operating a 4G wireless network. Rather, the authors view this model as the first of many steps in accurately identifying locations, investments, operating costs, and potential subsidies related to support of ubiquitous 4G wireless broadband coverage.

[2] This is an assumption that coverage is unnecessary where there are no households, businesses, or significant roadways.

Commercial Viability – Estimated monthly service revenues less adjustments provided by MTPCS were compared to the monthly costs of owning and operating mobile broadband network and services to determine a contribution margin for each Census Block. A Census Block with a positive contribution margin is considered commercially viable and not in need of support. A Census Block with a negative contribution margin is assumed to require additional support for a commercial operator to provide service. To determine the support funding necessary for non-commercially viable areas, the monthly negative contribution is multiplied by the number of users in the Census Block.

Model - Overview and Methods

Background

The primary purpose of the wireless network cost modeling approach is to support policy consideration relevant to emerging national reform for funding high cost service areas. To that end, the wireless model employed in this project is designed to estimate the financial impact associated with providing wireless services (including broadband data) to operating areas across the U.S..

The design logic, methods, and structure of the wireless network model used as the basis for deriving a forward looking cost to serve is accomplished through the application of CostQuest Wireless© ("CQWireless©") to specific operating conditions and objectives of the user. The underlying wireless network architecture is created through CQWireless© deriving investment and operating costs from inputs developed from industry averages for a rural carrier. The modeled architecture employs a granular approach, the use of spatial analysis, and a set of defined 'real world' engineering rules as the approach to modeling network design. The resulting bottom-up costing takes into account demand across all modeled services to establish minimum backhaul routing, traffic demanded at or traversing a network node, sizing and sharing of network components, and capacity and component exhaustion. Output unit costs are developed using a capacity costing technique and include all necessary plant, structure and electronics to support the designed network.

Overview of Modeling

The economic modeling employed for MTPCS develops an estimate of the network required to provide a desired level of service along with the costs of operating that network, including obtaining and maintaining customers on the network. The modeling of the network includes all components to prepare the service delivery system for productive use.

Central to understanding the resulting network topology created by the model is an appreciation of the underlying inputs, assumptions and economic models.

- Inputs, as outlined in this document, are based on publicly available data and verified against proprietary data for unit costs.
- Assumptions reflect real-world / current engineering practices, including how these practices are applied within specific terrain.
- The central economic model is a widely accepted, modern approach to network modeling practices used throughout the industry.

The model is designed to provide results at a Census Block level. Census Blocks are a standard unit of data collection and presentation thereby allowing for granular analysis of relevant information (e.g., infrastructure, demographic, and economic), including the cost to provide wireless service. Census Block data can then be rolled up into larger geo-political areas as desired (e.g., license areas or study areas).

Introduction to CQWireless©

CQWireless© is the configuration engine for the wireless communications network used in the cost model. It produces the network topology including tower counts, radio access network ('RAN') capacity configuration, backhaul type, etc.. The network design is a customized, forward-looking network developed on a customer-by-customer analysis of network utilization. The cost of the network is then developed within the model.

What sets the CQWireless© platform apart from other modeling approaches and methods is its granular approach, its use of spatial analysis, and its reality-based engineering guidelines. CostQuest model platforms are used by companies with operations in over 40 states in the U. S, have been used in property tax valuations, have been used to value networks in acquisitions, and have been used by international government agencies.

CQWireless© determines the topology for wireless network components, across all categories of plant required to connect specific customer sets to a serving tower and to provide a variety of wireless services to these customers. The model assumes the installation of forward looking, commercially available telecommunications technologies and uses generally accepted engineering practices and procedures. The design criteria was targeted to practical dimensioning of a deployable network and simplifying assumptions that underpin the logic, purpose, and the computational strategy have been employed.

CQWireless© Process

Locating Wireless Users

Because available data does not exist to precisely pinpoint the location of both business and residential populations customer demand must be estimated using a combination of secondary data sources. Within CQWireless© demand (e.g. population, number of households, housing units, business locations,) is derived from Census Block aggregated data. Using the Census Block data, Demand is distributed within each Census Block boundary based upon a random scatter process.

Take rates are provided as a user input and applied to the demand locations within a Census Block to determine the active subscribers and the resulting required network design.

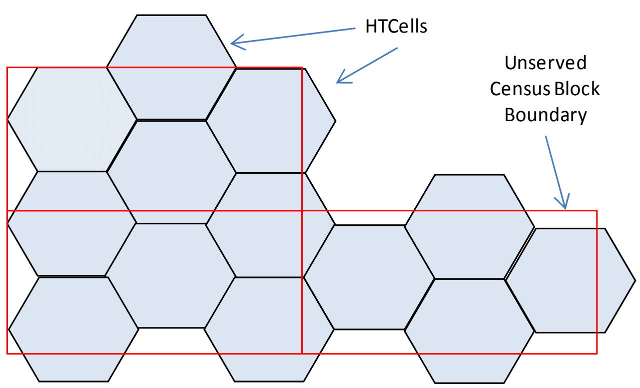
Coverage Approach

The methodology for creating coverage in the modeled wireless architecture is intended to produce a reasonable dimensioning of base station requirements for early stage network planning.

Existing tower sites can be incorporated into the model and used as the basis for existing coverage[3]. However, the model can also be run without known towers. In the instance where towers are not available CQWireless© employs a method using hexagonal tessellation cell (HTCell) to approximate site coverage in unserved areas.

HT Cell

The use of HTCell is symbolic of a three sector cell site and the hexagonal shape provides a method to simulate 100% coverage. The following diagram depicts a hypothetical overlay of HTCells in three Census areas deemed to be unserved by existing coverage. In this example, the unserved area could be covered by thirteen HTCells.



[3] The model assumes a fixed coverage radius for existing cell sites (see HTCell description).

For purposes of this model, each HTCell is assumed to house at least one antenna site. In the case where an existing site structure is used to place a new site antenna, the actual location of that tower is used in the model. In the case of a 'greenfield' build, the site is assumed to be at the center point of the HTCell.

The tower set that the model incorporated was created from a range of HTCell sizes from as small as ½ mile to 10 miles. The criteria for HTCell sizing included population density and terrain variation. Census tracts were used as the base geography for this process, but were split further into block groups in high density areas. As HTCells of different sizes are placed together, demand locations are routed to their nearest tower (within the HTCells) to create the service footprint of each tower, as shown below.

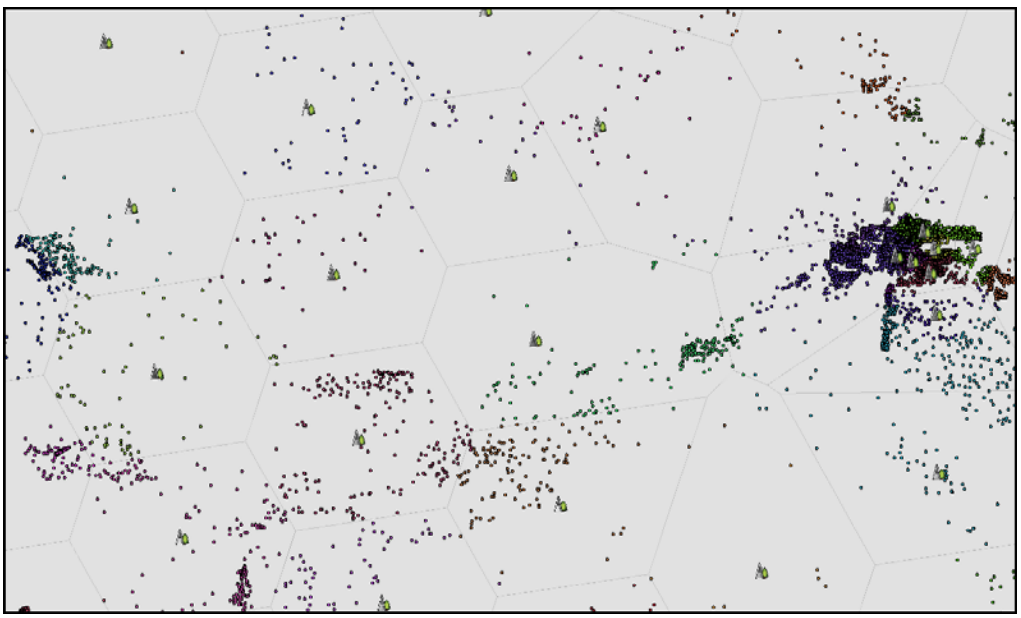


Figure 1---Demand locations within HT Cells

To deal with tower sites where demand exceeds the capacity of a single site, cell splitting methodology is used that results in the addition of one or more sites to meet the overall capacity demanded within the HTCell area.

It is important to note that variances in accuracy that occur at the HTCell will tend to be mitigated as the model is applied to larger aggregations of unserved area Census Blocks (e.g., in to market areas).

Backhaul Design and Investment

In today's market, landline backhaul is typically leased from another provider (typically a LEC). As such, the current version of the model loads in landline backhaul as an operation cost. In regard to

Microwave backhaul, the current version of the inputs assumes an average investment associated with all towers.

However, the model has the capability to capture the investment associated with backhaul at each tower if needed. The design for backhaul (also called second mile) of the wireless network involves the transport of traffic between an existing fiber point of interconnection (POI) (typically the MSO) and the deployed tower sites (Node 2 sites) in the identified service area. The backhaul design incorporates both fiber and microwave in an efficient manner. The model relies on a series of steps for the development of backhaul routes:

- Identification of existing fiber points of interconnection (POIs). For the MTPCS run, existing mobile switching offices were designated as fiber POIs.
- Association of cell sites to the nearest existing fiber point of interconnection (POI). The Node 2 sites are assigned to the nearest POI to create the initial spatial relationship (‘parentage’) that is most likely to provide least cost backhaul routing.
- For Node 2 sites subtending the same POI, the establishment of backhaul routes uses a spanning tree approach based on shortest distance routing to the POI. Beginning with the most distant Node 2 site, each site is routed to next closest cell site using the estimated lowest cost transport medium (i.e., fiber or microwave) subject to performance parameters of that medium.

An example of the implementation of the CQWireless© model logic for backhaul is shown below. The typical result is a site backhaul configuration that uses microwave beginning at the ‘edge’ of the unserved area and converting to fiber when microwave threshold constraints are reached.

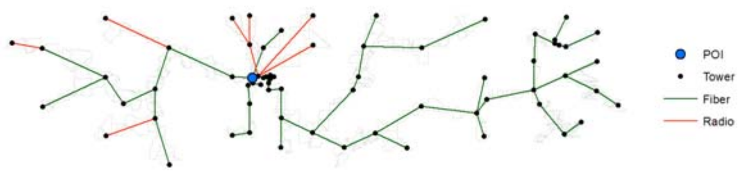


Figure 2--Backhaul routing

The use of microwave backhaul is subject to a link distance threshold. For this model, the maximum microwave link distance was set at 20 miles. If maximum link distance is exceeded the model assumes the site needs to be served by fiber.

The backhaul design is sensitive to the aggregate demand associated with linked sites in a service area. The methodology used is based on threshold bandwidth capacity of microwave links over differing distances. The use of microwave backhaul is also subject to a threshold parameter for the number of microwave links that can be supported at a single tower. This is a user selectable parameter. If the parameter is exceeded at a site, the model assumes the site needs to be served by fiber.

Output to Costing Component of Model

Once the CQWireless© topology/design is complete, two files per state are stored in the model databases. The DIST file contains information about the customers and Census Blocks, including the serving tower ID. The FDR file contains information about the serving tower and the backhaul components.

Cost Model Processing

Site Design and Investment

With the CQWireless© topology/design complete, the model uses a uniform design set of equipment and investment components for developing costs associated with the deployment of wireless coverage at each site. Since the model incorporates the use of owned and leased infrastructure (e.g., existing tower locations assumed to be available for commercial lease) via data or through a user provided input; certain equipment or investment may not be necessary at a site, instead operational costs of a lease are captured. Following is a summary of the key components used in wireless site design. This diagram is a depiction of standard site equipment and structure components.

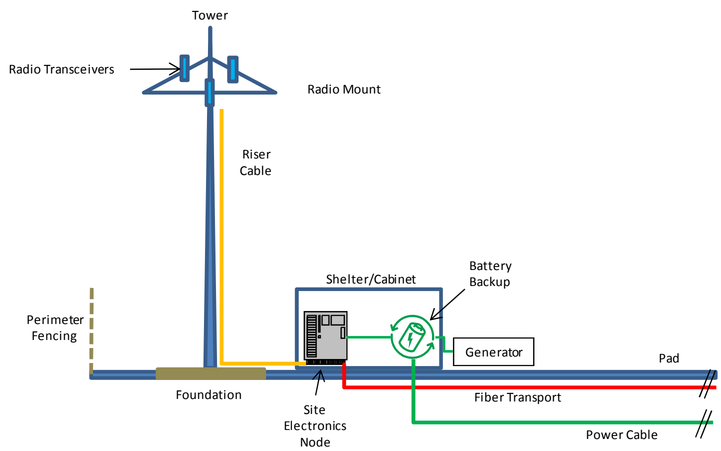


Figure 3--Typical site design

Radio Access Network (RAN)

This investment category incorporates site costs specific to the radio access function. Equipment in this category includes site based radio control, antenna costs, antenna cabling, radio frequency (RF) engineering and optimization.

Towers

Depending on ownership (which is an input in the model), this investment category can incorporate site costs specific to site preparation, tower structure, construction, and power necessary to support site operation including the radio access network. Equipment and investment in this category include site acquisition, zoning, fees permits, design and civil engineering, site preparation, tower, tower installation, utility connections, and on-site power supplies. Land is assumed to be leased.

For sites where an existing tower is leased, costs associated with tower structure and erection are excluded. Certain other costs associated with leasehold improvements, permits, and project management are included but are less than what is incurred at an owned site.

Huts/Shelters:

This investment category incorporates site costs specific to the shelter or 'hut' that houses certain electronic equipment, power control, and battery power supplies. These 'huts' are assumed to be prefabricated and subject to minor modifications to support site specific needs. Equipment and investment in this category include the hut, any modifications or retrofits to the hut, the foundation the hut is placed on, and the cost of placing the hut.

<u>Backhaul:</u>

As noted earlier, the current model assumes that landline backhaul is leased and is loaded in as an operational cost. And, microwave investments are loaded as the average across all towers.

<u>Network Core Design and Investment</u>

For the purpose of this model, the core network functionality is based on user input. Currently, the value is based on a value based on industry knowledge.

Operating Expense Input Development (Opex)

Recent publicly available financial reports were obtained for multiple wireless network operators. For this model, expense data was selected for a group of network operators representing the smallest tier (less than 700,000 subscribers) for which public financial data was available. The profile of these representative operators is summarized as follows:

Metric	Average
Covered POPs	4,500,000
Subscribers	524,478
Monthly Churn	3.5%

Operational Expense Apportionment:

In order to allocate operational expense in the context of the model, expense values are apportioned based on logical cost associations or 'drivers'. The following table shows the apportionment basis for each expense category.

CQ Classification	CQ Category	Apportionment Driver
Cost of Services	Cell Site Rental	Cell Site
Cost of Service	Cell Site Operations - Site Repair & Maintenance	Cell Site
Cost of Service	Cell Site Operations & Maintenance	Cell Site
Cost of Service	Cell Site Operations & Maintenance	Cell Site
Cost of Service	Transport	Cell Site
Cost of Service	Cell Site Utilities	Cell Site
Cost of Service	Usage - Local Call Termination	Subscriber
Cost of Service	Usage - Long Distance	Subscriber
Cost of Service	Usage - Data Content	Subscriber
Cost of Service	Other Network Operating Expense	Subscriber
Cost of Service	Roaming	Excluded
SG&A	General & Administrative Operating Expense	Subscriber
SG&A	Customer Service	Subscriber
SG&A	Billing Expense	Subscriber
SG&A	Corporate Marketing and Advertising	Subscriber
SG&A	Corporate Marketing and Advertising	Subscriber
SG&A	Bad Debt	Subscriber
SG&A	Regulatory Fees	Excluded
SG&A	Customer Acquisition Costs (excluding subsidy) per New Subscriber	Subscriber
SG&A	Equipment Subsidy per New Subscriber	Excluded

Because the publicly available financial records do not provide for expense categorization at a level of granularity consistent with the model, an industry average distribution was utilized to apportion reported expenses consistent with the above categorization and to derive adjustments to capture the difference in costs in operation in Rural, Suburban, and Urban markets.

Leased or Owned Site Indexing Development

The objective of this indexing is to identify and incorporate cost variances associated with cell sites that are owned and cell sites that are leased to derive investment appropriately related to each and derive a factor to be used as an estimate on proportion of new sites that will be built or leased in urban, suburban, and rural areas.

Approach:

Utilize 'owned' or 'leased' categorization of sites by market density type to determine the relative mix as a benchmark for the propensity to own or lease a site. These factors are then applied to determine the appropriate costing of sites in the model.

Propensity to Own/Lease			
Basis	Urban	Suburban	Rural
Own	20%	40%	60%
Lease	80%	60%	40%

Cost Model Inputs

All key inputs to and/or from these modules are captured or controlled by user input tables. At run time, the user then assembles the appropriate inputs into an "Input Collection" that then guides processing.

Before describing the user input tables, it is important to first understand what has been developed externally and loaded into databases

- The network topology as produced by CQW is captured in the CQW databases (one for each state). These topology capture the size and type of plant required. These are then converted into investments (i.e., capex) applying costs for material and labor provided in user input tables.

What follows is an inventory of the User Inputs that control CQW at processing time:

- ACF:
    - This table captures the Annual Charge Factors that convert Investment into its monthly costs. The current values loaded into CQW are produced by CostQuest's CapCost^{tm} model. This model has been used in the Benchmark Cost Proxy Model (BCPM) (universal service model) and by various telecom companies. The basis of the model is the economic determination of the depreciation, cost of money and income taxes associated with various plant categories. The calculation incorporates industry standard procedures, including: Equal Life Group methods, inclusion of future net salvage, Impact of deferred taxes, mid-year conventions, etc.
        - Key inputs into the derivation are: lives of plant, assumed tax lives, survival curve shapes, cost of money, and cost of debt, debt/equity split, and future net salvage.
        - Currently inputs
            - set Cost of Money at 11.25 percent
            - Use Depreciation lives consistent with those prescribed by the FCC's Wireline Competition Bureau's latest general depreciation order

  - Used to convert Investment into monthly values of Depreciation (DEPR), Cost of Money (COM), and Income Taxes (TAX)
- Bandwidth:
  - Provides the busy hour bandwidth
  - Used to size the appropriate network components
- Business Take
  - Used to derive the demand for the business market
- Capex
  - Provides the material and installation costs for the plant build
  - Data is applied against the network topology data from CQW to derive total build out investment levels
  - Inputs capture technology, network node and network function
  - Used to derive the total Capex
- COSize Adjustment
  - Defaulted to 1 (no impact)
  - Provides the user the capability to adjust the assumed purchasing power of small, medium and large providers
  - Currently, the inputs assume that all providers can achieve the same purchasing power (either as a result of their size or their ability to buy as a consortium)
  - Used to adjust up or down the Capex costs in the model
- Opex
  - Discussed in the Opex Module above
  - Provides the estimated operation costs to run and maintain a 4G network.
  - Used to develop the operation costs
  - MTPCS adjusted opex costs to reflect incollect/roaming loss
- RegionalCostAdjustment
  - Sourced from third party source - RSMeans
  - Provides the estimated difference in the cost to build and operate in each part of the county
  - Captures material and labor costs difference
  - Captured at the ZIP3 level
  - Used to drive differences in CAPEX and OPEX costs due to labor and material cost differences across the country.
  - Applied to All CAPEX and specific OPEX components
- StateSalesTax
  - Sourced from appropriate tax rates in each state
  - Used in CAPEX derivation
- Residential TakeRate
  - Used to derive the demand for the residential market.